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MOULDS FOR SYNTHETIC AND OTHER COMPOUNDS.

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Compounds.

THERE are very many different compounds in use for the production of mouldings at the present time, but seventy or eighty per cent. of the production falls under the following headings :—

(1) Synthetic Resin Bonded Compounds.
(2) Natural Resin (Gum) Bonded Compounds.
(3) Rubber Bonded Compounds.
(4) Hydraulic Cemented Bonded Compounds.

These are the moulded plastics, but in addition the moulding art is concerned with the production of laminated composite materials, which are not truly plastic. These include Synthetic

Resin Bonded Fabric, Paper, Pressboards, Fibre, etc., as well as Plyboards. All of these are made in the form of boards in simple moulds, or in the open press, and some of them, such as Synthetic Resin Bonded Paper and fabric compositions are moulded into various shapes in closed moulds.

The mould designer is called upon to design moulds for all these compounds, as well as for special compositions which have not been mentioned, and in deciding upon his design he has to have some knowledge of the characteristics of the material to be formed, to consider the shape to be produced, the number of pieces required, the time available for production, and the equipment with which the mould in question has to be operated.

Characteristics of Compounds.

As regards the characteristics of compounds it is, of course, outside the scope of this paper to deal with these in any detail, but brief mention of the outstanding points must be made.

Synthetic Resin Bonded Compounds are commonly of the phenol-formaldehyde class. They are in the form of a granular powder or of pellets, and are characterised by their peculiarity of assuming an infusible condition after they have once been properly moulded. When the compound is first pressed in the hot mould the resin melts, it flows around the wood meal or other filler, spreading the pigment and dyes into intimate contact with the filler particles, and the plastic mass finds its way into every cavity in the mould, thus taking the shape of the latter. In addition, a film of material, rich in resin, comes to the surface and takes an impression of the walls of the mould, so that if these are highly polished a corresponding finish is produced on the moulding.

This flowing in the plastic stage takes place in the first few seconds of the pressing operation, and in the course of the next few minutes the resin polymerises, changing into a permanently infusible material and acquiring new mechanical and electrical properties. After this change has occurred (and with good moulding powders this only takes two or three minutes with small pieces, and four or five minutes with large pieces) the mouldings can be ejected from the mould without any cooling, and without any fear of troublesome distortion. Only those who have seen a really successful moulding plant in operation can realise the beautiful finish with which these mouldings leave the mould, and the exceedingly fine polish on the mould surfaces which, under proper conditions requires no attention, but gets better in the course of use.

Natural Resin (Gum) Bonded Compounds are commonly made from shellac or bitumen, and mineral fillers such as china clay, magnesia, asbestos, etc. They differ from the Synthetic Resin Bonded Compounds in that they are purely thermo-plastic, i.e. they are moulded in the mould, squeezed to shape, and are cooled

so that they may solidify before extraction. The process is thus simply a melting, pressing and solidifying operation. These compounds require very much the same method of moulding as the Synthetic Resin Compounds, but they are generally more "flowable" and thus more liberties may be taken in regard to squirting the material from ledges and around projections, etc., in the mould. They take a high finish from the mould.

Rubber Bonded Compounds are entirely different from the foregoing in that they are not finished in the moulds. They are introduced in the form of pieces of plastic sheet material. The moulding forms into shape and begins to vulcanise during the moulding operations. Only the first part of the vulcanising process goes on in the mould, because to complete the vulcanising would occupy too much time and reduce the productivity of the equipment. After about ten or fifteen minutes pressing, the mouldings are discharged in an elastic condition. They have shrunk somewhat during the moulding operation, and will shrink further during the subsequent curing operation, which is usually carried out in live steam or in a hot air oven. These mouldings are very often made in soft steel moulds, the sulphur very soon tarnishing the mould surfaces. The pieces have to be machined where dimensional accuracy is required, and polished in order to obtain surface finish.

Hydraulic Cement Bonded Compounds are generally made from lime and silica and asbestos filling, or from Portland Cement and asbestos, various other inert mineral compounds being added to modify the properties for specific application. These compounds are hardly plastic, but they can be moulded into simple shapes. They are generally inserted in the cold mould in the form of a damp flocculent mass. The mould is closed under heavy hydraulic pressure, and the pieces are ejected almost immediately, then allowed to dry, and are finally baked at high temperature and cured in steam. These pieces are always made in hardened steel moulds, they have to be handled with very great care, and one of the difficulties of their manipulation is their abrasive nature.

The Synthetic Resin Bonded Paper and Fabric mouldings are made from sheet materials pre-coated with Synthetic Resin applied either in the form of a varnish or as melted resin. The pieces are cut up into appropriate sheets and carefully stacked in the moulds in such a way that the finished pieces will be formed with the least possible amount of disturbance of the structure of the material. The articles take a good polish from the mould. They are hardened in the same way as the Synthetic Resin Bonded Compounds already described. They may be extracted hot, and are characterised by great mechanical strength and superior electrical properties.

In general reference to moulding conditions it may be said that in modern moulding shops, Synthetic Resin Bonded mouldings are made at about 170° C.; Natural Resin (Gum) Bonded pieces

are moulded at 170° C. and discharged cool; Rubber Bonded mouldings are made at 130 to 150° C.; and Hydraulic Cement Bonded Compounds are moulded cold. The hydraulic pressure on the moulds varies from $\frac{1}{2}$ ton to 2 tons per square inch according to materials, shapes and size, and the moulding cycles vary from a minute in the case of the thermo-plastics, up to fifteen minutes in the case of the Rubber Compounds.

Types of Moulds.

Moulds can be classified under three headings: (1) Plunger Type; (2) Positive Flash Type; (3) Flash or Open Type; and may again be sub-divided: (*a*) Hand Moulds; (*b*) Semi-Automatic Moulds; (*c*) Fully Automatic Moulds.

Plunger Type Moulds.

The Plunger type mould is very rarely used in present day moulding practice, especially for the Synthetic Resin Bonded Compounds, being largely superseded by the Positive Flash and Flash moulds, but is used exclusively for the fabric and Hydraulic Bonded Compounds. The disadvantages of this type of mould can be given as follows:—

(1) Machining and fitting of plungers, especially for intricate contours, is costly; (2) Additional steel is required in the construction in order to obtain the required compression ratio; (3) The plungers tend to set up a scoring action on discharging and in time mark the mould shell, and consequently the moulding edges; (4) Should too much compound be charged into the mould the mouldings produced will be oversize as any excess cannot escape, as it is trapped between the top and bottom plungers. Hence it is important that only the correct amount of powder is loaded, which entails additional time and care on the part of the operator, thus increasing the cost of the mouldings.

It was to overcome these disadvantages that the Positive Flash Type was introduced.

Positive Flash Type.

This type of mould is a compromise between the Plunger or closed mould and the Flash or Open mould, and since its inception has helped considerably in the reduction of mould and moulding costs. In the main it consists of two members, the top plate or plunger, and the bottom plate which contains the mould cavity. In order to cater for the required volume of powder, a compression well is machined in the top face of the bottom plate, the moulding cavity proper being machined immediately below, and should the outer contour of the latter be intricate then the compression well can follow a more simple form and thus reduce machining costs. To prevent damage by misalignment it is essential that suitable dowel pins are added in either the top or bottom mould members,

the usual practice being to put these in the top plate as a longer pin can, in the majority of cases, be obtained.

The limitations to this class of mould can be summarised as follows :—(1) It is not advisable to make a multi-impression mould of this type because being semi-positive each impression must contain the same charge of compound, as otherwise should an excess be loaded into one impression, then the mouldings produced from the remaining impressions will be oversize and inclined to be "lightweight and spongy." Accurate weighing in this case is therefore essential and entails additional time and labour ; (2) Cleaning of the mould preparatory to the next charge takes a somewhat longer time, as the excess of compound has to be removed from the compression well ; (3) Mould construction is more elaborate, and a greater degree of skilled fitting is necessary. Despite its disadvantages this class of mould has its distinct uses, as will be seen later.

Flash or Open Type Moulds.

This is the simplest and most efficient of the three mould types, and combines the same essentials as mentioned for the Positive Flash Type, with the exception that no compression well is provided. The advantages of this class of moulds over the two types previously described are manifold. Less steel is used, extreme care in the weighing of compound is not necessary, cleaning of the mould cavities is simplified and mouldings are produced with a paper thickness flash at joint faces. Further advantages will be seen when we consider examples of mould design.

Hand Moulds.

Hand Moulds, as the name implies, are those operated and discharged physically on the part of the operator, and in the majority of cases are single impression types, although they can be, and are, designed and made with multi-impressions, these sometimes being referred to as "gang moulds."

There are concrete reasons why certain moulds are designed to be operated by hand, namely : (1) Intricate design of moulding ; (2) Cheapness of Tools ; (3) Press capacity available ; (4) Quantities required.

Taking Point (1) first :—In many instances the design of a moulding is so intricate that although the quantities warrant Automatic Moulds, these cannot be made to operate successfully as such, and it is then necessary to obtain the required production by substituting Hand Moulds which can be operated with greater facility and less expense. Hand Moulds are also made when it is desirable to keep the initial Tool Cost low, this being governed chiefly by the quantity of mouldings required. Press capacity available is a very serious consideration in many moulding plants and here again the Hand Mould shows to great advantage.

Points to be taken care of in the design of this type of mould can be given as follows :—(1) They should be as light as possible, but of such construction that they will withstand the great internal pressures set up under working conditions ; (2) Means must be provided to facilitate handling, i.e. discharging and loading. (3) Hand Moulds must be kept within a definite range of standard heights in order that two or more moulds can be worked together in one daylight.

Semi-Automatic and Fully Automatic Moulds.

Where a single or multi-impression mould is fixed on a press, and is parted by the return stroke of the press, thus requiring little effort to remove the mouldings, the mould is termed Semi-Automatic. If the press on opening is arranged to eject the mouldings completely, then the mould is termed Fully Automatic. As these moulds are closely allied to each other we can treat them as one type.

An Automatic mould may be heated either by standard steam plattens, or in special cases by providing steam channels in the mould itself, and in these cases rapid heating and cooling facilities are obtained, as these channels are usually very close to the moulding cavities. Automatic moulds are mainly multi-impressions, the impressions being let into the plates in the form of inserts, and the steam channels are drilled each way between the inserts. The bottom plate is then mounted on a block in which slide cross bars carrying the ejector pins. Four rods are fixed to the press head and pass through clearance holes in the cross bars, and are provided with nuts on the bottom ends. The press is then arranged so that the nuts on the rods commence to lift the cross bars about two inches from the bottom of its stroke, thus pushing out the mouldings for this distance.

The foregoing, of course, must be varied to suit conditions met with, but the essentials will remain the same. Special presses may be bought which incorporate a separate discharging arrangement, but the method described suitably converts a standard press for Automatic Moulds. Moulds for automatic operation are, except in a few instances, designed as Flash Types, and are excellent for large quantity production at a minimum operating cost.

I propose now to deal with a type, which from experience and use has proved very efficient, namely Semi-Automatic Moulds.

These may be sub-divided into two types : (*a*) Mouldings which may not be required in large quantities, but due to size require a large and heavy mould, which cannot be easily handled and must therefore be arranged so that the operator can work with the least possible amount of physical effort ; (*b*) Mouldings which are of such design that whilst the quantities may warrant a Fully Automatic mould, this cannot be conveniently arranged.

Relationship of Mould to Moulding.

Before commencing the design of any mould it is essential that certain information is available, in order that the ultimate mould, when put into commission, fulfils, as far as it is possible, the conditions laid down by, shall we say, the customer. We will assume that an enquiry has been received for, say, 1,000 moulded articles in Synthetic Resin Bonded Compound ; the rate of delivery to be 250 per week. Then the experienced engineer responsible for the mould design has, or should have, the following facts to work on :— (1) Design of piece and compound ; (2) Rate of delivery and total order ; (3) Accuracy and finish required.

The first point, that of Design and Compound, will determine whether the mould shall be of the Flash, Positive Flash, or Plunger Type, whether in turn it shall be hand or automatically operated, and point two, " Rate of delivery and total order " will further decide whether, in conjunction with point one, the mould be Hand or Automatic, the number of moulds required, and also the number of impressions to be catered for in the mould. Point one and two will also determine the treatment which will be required for the mould steel, i.e: whether it shall be hardened or left soft. Point three will ensure that the necessary allowance shall be catered for in the mould for subsequent machining operations which may be necessary on the moulding, to meet any special degree of accuracy that cannot be arranged for in moulding practice. It will again indicate whether the mould is to have extraordinary finish applied to it, such as highly polishing, etc. All these considerations must be dealt with individually, and in turn, collectively one with the other, and decision made before actually committing the proposed mould design to paper.

Moulds for Hard Rubber Compounds.

Whilst moulding compositions of the infusible types, i.e. Synthetic Resin Bonded Compounds, have superseded to a great extent, the Rubber Compounds in the last few years, there still remain distinct uses for rubber mouldings, especially in certain branches of the Electrical Industry where higher dielectric strength is necessary, and a survey of mould design for this particular class of mouldings will prove of interest to all concerned.

Rubber Compound is brought to the moulder in sheet form in varying thicknesses, and is of a soft spongy nature. Before being loaded into the mould it is the usual practice to roughly cut the " dough " as it is termed, to a shape convenient for moulding purposes and place it on a steam heated plate for a short time in order to make it more pliable. It is then pressed by hand into the mould cavities and finally formed by means of heat and pressure to the required shape.

Moulds for Rubber Compounds are practically all of the Hand

Type and made either as pure Half and Half or Flash Types, or as Plunger Types, the former being the one in more general use. The general construction of these moulds is to a certain extent similar to those already described for Synthetic Resin Bonded Compounds, with slight differences and variations to suit the moulding characteristics of this particular compound. As the excess compound or flash from a rubber loaded mould takes the form of a thin soft film, no cut off ledges are necessary, as in the case of moulds for Synthetic Resin Bonded Compounds, the main consideration in the design of the mould being to allow the excess to escape by the provision of suitable channels or grooves machined into the joint faces of the mould plates. The usual practice is to machine a V-shaped groove, the nearest edge of which is approximately $\frac{3}{32}''$ from the periphery of the moulding recess in the bottom plate, and following the shape of the recess as near as practicable. From this main groove lead off other secondary grooves, all running out towards the outside edge of the mould plate, the number of these being left to the judgment of the mould designer. However, when in doubt as to how many grooves should be allowed, it is a good plan to err on the generous side, as the more there are, the quicker can the excess compound escape. They also form a means of exit for trapped air, which is expelled from the mould with the flash. The top plate is again grooved in a similar manner. Dowels for locating the plates one with the other are fitted into the top plate, or the bottom plate, whichever is the most convenient, although the usual and best practice is to arrange these in the top plate, as generally a longer length of dowel can be obtained, thus allowing more "dough" to be placed into position to give the compression ratio required, i.e. two to one.

Certain mouldings are of such design that the Flash Type Mould cannot be conveniently used, and in these cases the Plunger Type is substituted. It is very necessary, in the case of the Plunger Type to make adequate provision in the form of V grooves to allow the excess compound to escape, and these again are machined into the moulding faces of the top and bottom plungers and led to the outer edges and up the sides. The shell faces, top and bottom, are also grooved so that every chance is given for the overflow to get away. It is of paramount importance to make the walls of the outer mould shell sufficiently strong to withstand the high pressures induced under moulding conditions, this especially applying to long sides of rectangular shaped shells, as these are more liable to distortion unless made of a strong section.

Inserts can be moulded in with more ease in the case of Rubber Compounds, loose pieces in the mould construction not being so objectionable as in the case of moulds for Synthetic Resin Bonded Compounds, because when plastic, the material does not tend to bind and cause the mould members to stick. Discharging is made

easier, as in many cases the mouldings can be somewhat distorted in order to obtain easier extraction, due to the piece being elastic when ready to leave the mould.

Moulds for Hydraulic Bonded Asbestos Compounds.

This compound is of the cold moulded class, being moulded under the action of pressure only. It cannot flow with the ease of either Synthetic Resin or Rubber Compounds, and ledges at joint mould faces should therefore be rigidly avoided. Moulds are designed as Plunger Types only, and compression necessary is in the ratio of some three to one. Inserts can be moulded in position. It is not advisable to mould holes right through, as pins are more liable to breakage, and moulding pins are recommended to be designed so that the position of the hole or holes is only spotted, these holes being drilled through in the moulding afterwards.

The material, as handled by the operator, is of a loose fluffy nature akin to, in appearance, " bed-flocks " and is slightly damp. The operation of moulding is much quicker and cheaper than the hot moulded compounds, and for general purposes is as follows :— The required volume is charged into the mould, this in its essentials consisting of an outer shell with top and bottom plungers shaped to the form of the piece to be produced, the top plunger assembled, and the mould centralised under the press. The press is then closed and allowed to dwell for a few moments under full pressure and then opened. It is sometimes necessary to use a thin shim plate on the top plunger in order to take care of the reactionary pressure peculiar to mouldings of this class of compound, and thus a final squeeze is given with this shim plate in position. The press is then re-opened, and the mould discharged by suitable means, either by provision on the press or the discharging bench. As in the case of Rubber Mouldings, the article is not completely cured on leaving the mould, but in this case great care has to be exercised in the handling, as the mouldings can very easily be broken at this stage. Further curing is effected by placing the mouldings on suitable trays and allowing them to dry at room temperature for a period of four to five days according to the size of the article, finally being cured by placing in a hot oven for some hours, in order to evaporate any moisture left in the compound. For simple shaped mouldings the mould design is in itself very straightforward, but should it not be possible to obtain a straight discharge, then it is usual to design the mould either with split liners or loose mould members, in order to avoid breaking the moulding when extracting. As this material sets up a scoring action on discharging from the mould, it is a sound policy to harden all moulds of this type.

Moulds for Textolite Compounds.

Articles of intricate shapes cannot be moulded in this material, although it is possible to produce mouldings which cannot be

moulded by using the sheet material, by substituting material which has been shredded into small pieces. This process, however, is somewhat expensive and is only resorted to for special cases where cost is of secondary importance. Gear blanks, rolls, spools and similar articles are the most common types of mouldings met with. Inserts are not, as a rule, moulded in this material, although in the case of the gear blanks metal centre inserts are sometimes moulded in position. Moulds are invariably of the closed plunger types and are hardened in order to withstand the abrasive action of this material, which tends to set up scoring on discharging from the mould.

In the case of flat mouldings, the pressure required to produce a homogeneous moulding is transmitted through the medium of the top plunger in a vertical direction, but when such articles as flanged spools are required then the mould design must cater for a two-way pressure, i.e. a horizontal as well as a vertical pressure.

Let us consider a mould designed for producing small Synthetic Bonded Fabric Spools. The mould consisted of a shell, the inside being bored to suit the tapered split liner, and the moulding form machined inside the latter. A top and bottom plunger and a centre pin were provided for forming the flanges and centre hole respectively, all parts being hardened. The mouldings are made thus : Blanks of fabric are cut to conform to the shape of the two end flanges, and a further strip cut to the form of a rectangular piece, which is then bound around a mandril the same diameter as the centre moulding pin, and the two end and middle flanges slipped on to the roll formed, one or two as required. These are then pushed on to the mould centre pin, and the halves of the split liner loosely placed around and dropped into the tapered shell. As the pressure is gradually applied the tapered split liner is forced down through the medium of the plungers, and whilst the latter gives a downward pressure on to the flanges, the split liner, as it moves inwards on its taper, gives also a sideways pressure and thus squeezes the centre roll of fabric, the combined pressures thereby forming a moulding which is perfectly homogeneous. This two pressure action is the fundamental principle of moulding all Synthetic Bonded Fabric materials, whether paper or linen, where horizontal as well as vertical pressures are needed.

Mould design for the compound known as Synthetic Resin Bonded Paper is in principle the same as for Fabric Compounds, the only difference being that no shrinkage allowance is necessary in the mould.

Mould Design.

Having touched in general upon the various compounds and their moulds we will summarise cardinal points on Mould Design for reference of the mould designer. Fundamental points for all

types of moulds, irrespective of the compound to be used, can be tabulated as follows :—

(1) Carefully consider joint faces, and where possible arrange the moulding cavity in the bottom mould member. Attention to this point will invariably help the compression factor required.

(2) Remember that the moulding when made must be discharged cleanly and efficiently. Vizualise how the operator will need to handle the mould for this purpose and provide the necessary means.

(3) If in doubt as to which half of the mould the moulding will stick when parting the mould, provide discharging means in *both* plates.

(4) Remember that certain compounds shrink upon cooling and therefore shrink *away* from cavities and *on* to plungers.

(5) First consider the mould operator and production, *then* the tool maker. In other words do not sacrifice production to save labour in the tool room. It does not pay in the long run.

(6) But *do* consider how the mould is to be machined. Remember that a solid mould is preferable to a built-up mould and therefore avoid loose pieces if it is at all practicable.

(7) Arrange locating dowels so that the mould is "foolproof" on assembly. To make sure it is sometimes beneficial in this respect to include a fouling pin.

(8) Moulds to be operated by physical effort must be as light as possible but strong, and further remember that the majority of moulds are handled at high temperatures.

(9) If a mould is to be hardened, and this is advisable in most cases, do not call for a casehardening steel for intricate designs where distortion due to heat treatment is liable to occur. Use an alloy steel even though more expensive.

(10) Determine a series of Standard Mould Heights and stick to them. By this means more than one mould of standard heights can be used under one press daylight.

(11) Avoid knife edges on mould members.

(12) Taper all mould members where necessary, as the longer the taper, the easier is discharging.

(13) Do not expect to hob mould cavities if the maximum taper allowable on the moulding is slight, or disappointment and unnecessary expense will inevitably occur.

(14) Provide curing plates and fixtures if it is necessary to keep the moulding quite flat; remember that some mouldings tend to warp and distort on cooling.

(15) Chamfer all edges of mould members where these have to slide one with the other. This will prevent burrs and interference. A standard chamfer is approximately $\frac{5}{32}''$ at 15°.

(16) Allow a minimum of 8° taper each side of split tapered members and provide parting slots.

Other considerations can only be obtained from experience and the special circumstances governing the design in hand. It is a true saying that every new mould is a problem in itself, and can only be solved by applying the experience gained from the design and use of mould after mould. Even the experienced moulder when operating a new mould considers himself extremely lucky if he obtains a sound moulding after one or two trials, and often many mouldings are made and scrapped before a satisfactory solution of the best methods to be applied for a particular mould is arrived at.

Construction of Moulds.

As already mentioned moulds should be as simple as possible, contain the least number of loose parts, and should be made solid if practicable. There are, however, many cases where it is advisable to construct the mould of individual pieces, in order that, in the first place, expensive steel is used only for the actual moulding members. Secondly, to reduce machining costs, and thirdly, to facilitate discharging. This particularly applies to Semi-Automatic Moulds and moulds with multi-impressions, where otherwise it would be more or less impossible to construct the mould by other means.

Hobbing.

A great amount of labour and time used to be spent in making moulds to produce mouldings which, due to their design, necessitated intricate machining and fitting, the results from the mould in many cases being crude when compared with present-day mould practice. For instance, if we take a simple knob moulding, thousands of which are in everyday use on wireless sets, etc., it will be readily understood how difficult a machining proposition it would be to produce a mould which would give the straight knurl or sunken lines, figures, letters, etc., which are required on this particular class of mouldings.

In the early days of mould construction for these pieces, it was the practice to machine out as much of the moulding cavity as possible, and either file or broach out the flutes for producing the straight knurled portion, afterwards blocking up the hole at the bottom from the underside of the mould plate by inserting a separate piece, this being driven or pressed home into position. This method, especially when the mould had several impressions, was slow and expensive, and invariably gave trouble in the Moulding Department, with the consequence that output was slowed up and maintenance for tool upkeep was considerably increased. The mouldings instead of being smooth and of good appearance, left the mould with a fin or flash of compound at the point where the

mould joint had to be made, and despite polishing and buffing, often proved unsightly. In the case of sunken markings, figures and letters, etc., which were required on most of these mouldings, these had to be engraved on the article after moulding, which naturally increased the cost considerably.

To overcome the difficulties mentioned, and in turn cut down manufacturing costs of both moulds and mouldings, the design of which did not permit of straightforward tool room practice, experiments were tried whereby a replica of the outer shape of the moulding including any markings which might be required on the flat faces, was made in steel and hardened, this being forced under enormous pressure into a blank of soft steel. The results obtained were very gratifying, although it took many months of experimenting before a reasonable idea could be formed as to what could be achieved by this method. Thus we have in present day mould practice a means of producing moulding recesses of intricate shapes, which are formed at one pressure and present solid moulding faces to the moulding compound, with beneficial results to production as a whole.

Hobbing, as this method is called, can be defined as the formation of the reverse shape of any article into a blank of soft steel by means of pressure exerted on to a Master Hob. By this means a mould or number of moulds containing identical impressions can be economically and quickly made. The method employed is as follows :—

A Master Hob of hardened steel and shaped to the form of the moulding to be produced is made and then highly polished. A blank, or number of blanks, depending on the number of impressions required, is made from soft steel, the top face being finished perfectly smooth and also highly polished. The outer diameter of both the shell and hob is made sufficiently strong to withstand the enormous pressure set up under the action of hobbing. The outer diameters only of the blank and hob are well lubricated with grease, usually vaseline, the blank placed into position at the bottom of the hobbing shell, the hob located in the top portion of the shell and resting on top of the blank. The whole is then placed under the hobbing press, the press closed gently until the pressure exerted is transmitted through the medium of the hob to the blank and continued until the shaped form of the hob is forced into the blank. The pressure required is, of course, proportionate to the area of the cavity to be hobbed, but is in the region of some 200 tons per square inch. The press is opened, and the hob and blank pressed out of the shell and the former tapped lightly until it is released from the blank. The blank is then set up true with the impression and the surplus material machined away until the desired size of inset is obtained, after which it is casehardened, ground, finally polished and fitted into the mould plate.

All hobs should have liberal tapers, and unless the moulding

permits of good drafts, then the method of hobbing should definitely not be employed, otherwise labour which could be better employed will be wasted and money thrown away. For example, it was intended to hob the impressions for a mould which was to produce a moulded hexagon nut, this being $1\frac{1}{2}''$ across the flats by $\frac{3}{4}''$ deep. The maximum amount of taper allowable on the sides of the nut could not exceed 4° included, but we determined to try hobbing, the ultimate results being as follows :—

First Trial.—A blank of soft mild steel highly polished at the top face was made and the hob, which was hardened, pressed into this under a full 300 ton pressure.

Result.—The impression made was approximately $\frac{5}{8}''$ deep and at this depth the metal began to split and shear.

Second Trial.—In order to prove whether a satisfactory hobbing could be obtained with the blank annealed, a further blank was made in the same steel as used for the first trial, and an existing hob, similar in shape, ground to the same taper. The blank was then heated to a dull cherry heat and this hob forced in under 300 tons pressure.

Result.—The blank shrunk on to the hob and in endeavouring to extract, the hob broke.

Third Trial.—A further experiment was tried by boring a hole approximately $\frac{3}{4}''$ deep, the scheme being to help the displacement of metal, the diameter being about $\frac{1}{8}''$ smaller than the size required across the flats. The hob again was forced home under 300 tons pressure.

Result.—The hob broke and to extract it, it was necessary to anneal the blank and hob together, and then bore out from the back face of the blank and force the broken hob out. Here again the hobbed impression showed that the steel had commenced to shear and break up.

Undoubtedly it was proved that the amount of taper allowed was insufficient to displace the necessary metal without fracture, as this was practically under a shearing action. This can be proved, as hobbed impressions for producing wireless knobs were entirely satisfactory, these having as much as 30° included taper.

It is very important that blanks intended for hobbing purposes should have at least 70 per cent. of the metal, which is to be displaced by the hob, machined away. In some instances it has been found to give better results by turning off metal at the edges, whilst in other cases a depression on the underside of the blank will give the desired results. In the latter case, however, discretion must be used, as should the impressions required be deep, then invariably the metal will collapse, and here the author would recommend that the surplus material be taken off at the top and bottom edges. When it is necessary to hob raised letters or portions of a surface, which are to stand proud of the main face, experience has proved

that it is better to leave the blank solid, as a resistance is then created to the applied pressure, thereby causing the displaced metal to flow upwards into the hob cavities. In these cases, however, the outer shell should be made of sufficient strength to withstand the enormous pressures set up, as shells have been known to split, and when a pressure of some 1,000 tons is applied it does not require much imagination to understand the serious consequences which may result should a shell split and fly apart.

Summarising.—The following points must be carefully considered on all hobbing problems :—(1) Unless tapers are liberal, do not use the hobbing method ; 8° taper per side is recommended as a minimum for all impressions deeper than $\frac{1}{4}''$. (2) Decide approximately where the displaced metal in the blank will flow and remove a proportionate amount from the blank, preferably at the edges. (3) If raised figures, etc. are required, then a minimum amount of metal should be removed from the edges and in some cases the blank must be left solid. (4) Highly polish both hob and top surface of blank.

Screw Threads.

Where it is necessary to have threaded holes in mouldings of the Synthetic Resin Bonded Compounds, it is the rule, rather than the exception, within certain definite limits, to mould, instead of machining these, as a moulded thread has much to commend it over a machined thread, because during the operation of machining, the surface or skin of the compound is broken down and should the thread be of a fine pitch the results are very unsatisfactory. However, should screwed holes of a size smaller than 4BA be required it is advisable to cater for these by moulding metal inserts containing the required thread into the moulding, but it is recommended that designs of mouldings should, where the choice is optional, call for moulded threaded holes to be as large as practicable, combined with a suitable coarse pitch. B.A. threads are not desirable, although sizes from 4BA downwards can be moulded if required. In some cases holes 9BA $\times$ $\frac{1}{2}''$ deep have been asked for in mouldings, but needless to say these have *not* been produced. The start and end of the threads of the screwed pin producing the moulded hole should be finished off in the form of a well-shaped V, as otherwise, the corresponding moulded thread at these points will be very weak and chip in service. Where two mouldings have to mate, such as for instance a threaded stud and nut, it is important that suitable allowance is made on the mould pin in order that the pieces will assemble together without undue pressure being required. To obtain this condition it has been found that allowances varying from .006″ to as much as .020″ according to the diameter and depth of thread being moulded, should be added to the mould member producing the threaded hole, and it is the practice to

establish the plugs moulding the threaded hole with this clearance added, whilst the member producing the male thread is kept as near the theoretical size as possible.

As we have seen, Synthetic Resin Bonded Compounds shrink upon cooling, and as the moulding screws for producing moulded threads only have this shrinkage allowance on the outside diameter, and the moulding threads are usually cut on a lathe having a standard lead screw, it will be understood that, should there not be any additional allowance made over and above the allowance for shrinkage on the diameter, then when cooled, the pitch of the thread must be incorrect by the amount of shrinkage which takes place in a longitudinal direction. This error on moulded threads is very noticeable when a screw has to enter a hole more than one full diameter.

Should it be necessary that a male thread has to be screwed, say, one diameter or more, into a female thread, and be a good fit right through the whole length of the threaded portion, then the most satisfactory arrangement would be to cut the mould screw on a lathe which had a special lead screw incorporating the shrinkage on the pitch, so that the thread cut would naturally have this pitch error included. This practice, however, is hardly warranted as it will be found for commercial purposes quite satisfactory to make the additional allowance on the diameter as already mentioned. Threaded moulding pins should be shouldered at approximately 90° included angle, as this then forms a countersunk start in the moulded hole and facilities entry of the mating screw.

Curing and Discharging Fixtures for Moulds.

In many cases mouldings must be kept flat after discharge from the mould, and in these cases it is customary to provide special means in order to prevent warping of the moulding as it cools.

The methods employed may be very simple, or on the other hand rather more intricate, it depending on the size and shape of the piece to be cured. In the case of large flat mouldings usually two machined plates will meet the requirements, the moulding being placed between them, and suitable weights placed on the top plate. Another method is to employ a simple " book press " and place the moulding between the plates and keep it under pressure whilst cooling by means of the screw. According to size and shape so will the means required to prevent warping be necessary, but it is of importance for the mould designer to cater for this possibility and provide suitable means ; otherwise although the mould design is all that can be desired, the finished results of the mouldings produced from it will be very disappointing.

The same remarks can apply in the main to discharging facilities for moulds. In many cases this important point is, unfortunately, apt to be overlooked and mould designers wonder why the products

from the mould do not come up to expectations. The ultimate discharge of any mould is of great importance, and is in fact the governing factor in efficient mould design. The design of Automatic and Semi-Automatic Moulds usually looks after this point, but the hand type of mould should be catered for, as circumstances permit, just as much as for Automatic Moulds. Much damage can be done to a mould by careless handling and hammering due to no special appliances being provided in the layout of the mould, and when production is at stake one can hardly blame an operator for taking extreme means to discharge a mould in order to fulfil his quota of the day's production.

Steel for Moulds.

Steel plays an important part in mould practice and the trend to-day is towards the higher grade alloy steels rather than the carbon steels. Generally speaking mild steel is not satisfactory for mould construction especially when the moulding compound is of an abrasive nature, such as the Synthetic Resin Bonded Compounds.

For mould insets and moulds of a simple nature, the low carbon steels can be, and are, used to a certain extent, but in the main their application is very limited and in the author's opinion should be avoided. It is, of course, necessary to employ the softer steels for hobbing purposes, afterwards carburising and hardening, but where machined mould insets are to be used then it is definitely a sound policy to make these in an alloy steel. Mild steel moulds are not satisfactory in service; they tend to crush and develop cracks, and in many instances the hard case chips off, especially at mould edges; they tarnish and will not retain a high polish.

From the cost point of view any mould is, comparatively speaking, expensive as much skilled labour needs to be applied to its construction and it is essential that unnecessary risks are eliminated right from the commencement by the use of a suitable steel. One cannot recommend that any particular alloy steel should be specified for moulds, as many steels are at present marketed which have been developed specially for this purpose, although mould manufacturers differ in opinion as to which is the most suitable. Steel manufacturers, realising the importance of the moulding art, no doubt will in time produce what may be termed the ideal mould steel which will be sold at a price comparable with the mild steels, and should combine the following properties :—

(1) Moderate cost; (2) High tensile strength with toughness; (3) Stainless; (4) Be fairly easy to machine; (5) Not move or distort during hardening; (6) Not chip at surfaces during service. When we have a steel embodying all these points, then the cost of moulds and mouldings will be appreciably reduced and a decided step forward made in moulding practice.

Extreme care should be taken in the hardening of moulds and mould members, and steel manufacturers' hardening instructions faithfully observed in order to eliminate scrap and risk of failure occurring in the moulding department. The old saying, "Penny wise pound foolish," rings true in the case of moulds made in the carbon steels, even where it is possible to rectify distortion by grinding. Steel for hobs should be capable of withstanding the enormous pressures necessary for hobbing practice, whilst retaining a certain toughness to prevent breakage, this being a common fault with most hobs.

Summary.

One cannot close without mention of the future of the moulding art and its great possibilities for the commercial as well as the electrical and engineering industries. The ease with which mouldings can be produced, their accuracy and comparative cheapness, good appearance and artistic design, are factors which will have an important bearing in the replacement of similar articles at present being manufactured in other materials at a higher cost, and we shall, without doubt, see startling developments in the near future.

Mouldings are at present being produced for commodities used in the home, such as tea sets, trinket sets, lamp holders and other articles too numerous to mention, and with a little imagination one can visualise such articles as furniture, panelling, etc., being produced with the same ease as the smaller mouldings of to-day, as there is no doubt we are at present only touching the fringe of possibilities.

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In conclusion, the author desires to express his indebtedness to the following for the assistance given in the preparation of this Paper :—Messrs. British Thomson-Houston Company for permission to give this Paper ; Mr. Warren, Chief of Engineering Laboratory, Rugby Works, for information on Compounds, and loan of slides and mouldings ; Messrs. Jackson and West, Planning Department, for assistance with illustrations ; Mr. Rivitt, Data Section, for preparation of slides.

Discussion : Coventry Section. (6th November, 1929).

Mr. E. W. Hancock, who occupied the chair : Well, gentlemen, I feel sure that we have all listened to a thoroughly interesting and instructive paper. The paper to which we have just listened, deals with a subject with which, as production engineers, we are not so familiar, but I expect and trust that there are many gentle-

men here who will take part in the discussion. For myself, I know very little of this subject, and have been very interested in the paper. Even on this subject of mould design, which is slightly out of the usual run of production problems, I was able to trace many similarities of the fundamental problems of production. This being a further indication, that whatever the product may be certain fundamental rules apply.

Mr. Richardson made two remarks which interested me very much. He says: "Do not sacrifice production to save labour in the tool room," and "every new mould is a problem in itself." Regarding his remark not to sacrifice production to save labour in the tool room, we have here the equivalent of the designer's point of view which I heartily support, namely, that the ideas of the designers should not be cramped by the methods of production. This remark is even more interesting, coming as it does from Mr. Richardson, whose work comes within the sphere of production. Regarding Mr. Richardson's remark that every new mould is a problem in itself, this remark is connected again with the question of design, and is true of production problems generally. If we, as production engineers, give the designers the freedom which they should have in meeting competition by producing a product which includes improved and better ideas, then it is part of the production engineers' outlook to anticipate fresh problems with every fresh piece of design, and so maintain sufficient flexibility of thought so as to respond as quickly and as efficiently as possible to the designer's requirements. There are one or two queries I would like to raise, which I hope Mr. Richardson will deal with during the discussion. Within what limits should the temperature be kept for heating the moulds? and what degree of importance is attached to the variations of temperature? What accuracy can be obtained, say, for instance on the 3″ diameter mould, as, although I noticed well laid out charts for giving shrinkage allowances, I would like to know, even with this well considered allowance, what is the minimum variation to be expected. Mr. Richardson's specification for an ideal steel, I think, interests us all, and if such a specification were available, many of our problems would be overcome. The fact is that Mr. Richardson has, however, asked for something which at the moment appears to be impossible. There is reason to believe, that in the course of time, some such steel will be available, and certainly there is no harm done in letting Steel Manufacturers know the ideal steel required. In connection with mould steels, I would like to ask Mr. Richardson, what is in his opinion the best steel, especially in connection with the high pressure work. Regarding the question of the "flash" on these moulds, I would like to know how this "flash" is removed, whether by hand or machinery. Some of the automatic moulds look to be very interesting, especially one which produced approximately 250 parts per hour. I would

like to know what process is adopted for filling these moulds, as there seemed to be approximately twenty to twenty-five on the one load, and the filling time, might easily be the largest operation; if so, what is being done in this respect to increase the production per hour? I would also like to know what class of labour is used for operating these machines, as to whether skilled labour is necessary in handling these more expensive moulds. In conclusion I like to congratulate Mr. Richardson on his paper; not only upon the paper itself, but upon the thorough manner in which he has prepared and presented it to us. The meeting is now open to discussion, gentlemen, and I trust that you will pay Mr. Richardson the best compliment you can, namely, by entering into a discussion and raising the many queries which I feel sure you have to raise.

MR. E. J. EDGAR: May I ask why you make a polished surface to the base that you are going to hob? Does that retain the surface after the hobbing?

MR. RICHARDSON: In reply to Mr. Edgar's query, it is necessary to highly polish the hob face in order that the face at the bottom of the hobbed recess retains this smooth finish, and as hobbing is mainly resorted to for intricate shapes it would be very difficult indeed to smooth and polish these recesses afterwards. Unfortunately, we can only hob in the low tensile steels and they do not retain the polish in service as in the case of the chromium alloy steels.

With regard to the various questions our chairman has asked. The temperatures of moulds vary for different compounds. For instance, some are moulded at 145° C., some at 150° C., and others at 170° C., and it is advisable to keep within the moulding temperatures recommended by suppliers to, say, two or three degrees up or down, otherwise excessive heat will cause blistering and insufficient heat will not produce sound mouldings.

With regard to accuracy of mouldings produced from a mould, I presume you are referring to Synthetic Resin Bonded Compounds, an allowance is made in the mould for shrinkage so that when the moulding cools we try to strike as near as we can the size called for. Take, for instance, a moulding three inches in diameter, as mentioned, then an allowance of approximately .018" is added in the mould for shrinkage, and providing the compound and temperature, etc. are correct, then we may get within, say, two or three thousand, but I do not think we can lay down any hard and fast rules. In special cases we can hold a moulding to a close limit by taking special precautions in the curing of it by placing a curing plate in position to hold the moulding to size as it cools. On the question of the best mould steel. I have given what I consider the ideal steel, but I should not like definitely to state what, in my opinion, is the best steel because there are many marketed, each of which are known to give efficient results. We use a steel which

has a ductility of some twelve to fifteen foot pounds, and at the same time has a tensile of 100 to 110 tons per square inch when heat treated. We have tried other steels which have given satisfaction, but unfortunately the price has been too high. I would recommend a steel giving a Brinell of approximately 480, not more, and if anything slightly under that figure. Trimming or burring of mouldings depends upon the type of mould and the pressure used. If the mould is right and the pressure correct, then the flash is at the most four to five thousandths of an inch ; in fact, it is almost transparent and the removal is simplified considerably. Removal of the flash is generally done by hand on the bench or by buffing and polishing, and in other cases by making special tools and skimming off in a bench lathe. The filling of a multi-impression mould is done by loading with compressed tablets, a number, usually one, of which is placed in each cavity. It is the practice sometimes to make a special loading device whereby the tablets are placed in the mould cavities simultaneously.

With regard to the question of labour. Unfortunately, we cannot use female labour to any great extent at present in moulding practice. If any of you have been in a moulding shop, especially on a hot day and seen the men operating these moulds you would appreciate why we employ male labour. We have to use male labour and in the majority of cases the strongest male labour we can get. That is the great point I raised in the paper when dealing with hand moulds, that these should be kept as light as possible in order that every help should be given to the operators. As a rule unskilled labour is obtained and trained so that in time they develop into semi-skilled operators, and a great deal of money can be wasted by unskilled grades of labour damaging expensive moulds.

Mr. Mansfield : With regard to no taper. As I happen to be in the glass manufacturing industry, this is raised very often. We overcame that difficulty by making the moulds in two halves so that they could be opened and shut. I do not know whether they could be applied in this, but it is very successful in glass manufacturing. There is also the question of eliminating air from the moulds. What line do you take for doing that ? In glass it plays a more or less important part. Also whether you have ever tried phosphor bronze moulds ?

Mr. Richardson : If I understand you rightly you are referring to the split type of mould, which is used to a large extent, but is expensive. We find from experience that designers of mouldings are very apt to tie us down to fine tapers and whilst mouldings can be produced to these straight or very fine tapers, it generally means making special facilities by designing the mould to split, and no doubt if we could get to rock-bottom facts we would find that the design of the moulding could stand a much larger taper than is

allowed us. With regard to the elimination of air. If you have a deep mould or one with deep cavities, it is sometimes necessary to get rid of the air, which would cause blistering in the moulding, either by putting in compressed tablets specially shaped to the mould, or else by packing in powder into the deeper recesses before filling in the balance of the powder. In some cases the mould is, what is termed, "breathed," that is, the plunger is very gently closed a certain distance and then opened to allow the air to escape and then the full pressure put on the plunger immediately. So far as phosphor bronze moulds are concerned, I believe they are used to a great extent for rubber mouldings, but I have not had a great deal of experience with them. I have also seen white metal moulds, which are very similar, but that again is another branch of mould design.

MR. SHARP: Has electrical heating any advantage over steam? I should think it would be quicker and you would have no flexible pipes to contend with, or joints.

MR. RICHARDSON: We use both, but mainly steam. I think the general opinion is that steam is superior for heating purposes to either electric or gas heating appliances. Steam is our standard method, it gives a more latent heat and is easily controlled.

MR. BOOTH: I have been very interested in the lecture and there is one question I should like to ask and that is, can the lecturer give some idea of the tensile strength of the material he produces?

MR. RICHARDSON: From information supplied by our laboratory it is about two-and-a-half tons per square inch.

MR. ROBINSON: May I ask Mr. Richardson if he has met with cast alloy steel moulds at all, or if they have dealt with that question?

MR. RICHARDSON: I have had no experience in that line.

MR. ARCHER: With regard to threads. Have you had experience with Whitworth, or square threads? Or whether there is any distinct shape of thread?

MR. RICHARDSON: So far as the mould used is concerned, I do not think it matters what shape thread is moulded.

MR. KAY: Has any special care to be taken to prevent distortion after the moulding has been removed?

MR. RICHARDSON: There is moulding here and there that requires special care in this respect. There is this radio cabinet, the walls of which are not more than $\frac{5}{16}$" thick, probably less. This interesting moulding is produced in 700-ton presses and in this particular case they rely upon the distortionment of the moulding to eject it.

MR. HUGHES asked for information as to discharging mouldings.

MR. RICHARDSON: Every press should be fitted with side discharging rams. In the majority of automatic and semi-automatic moulds the definite discharging pressure ranges from five to fifty tons, whichever is needed.

MR. BOOTH, at the close of the discussion, moved a hearty vote of thanks to the speaker, which was adopted with acclamation.

Discussion: Birmingham Section. (13th November, 1929).

MR. J. A. HANNAY, President, Birmingham Section: I do not remember any lecture that has gone on the lines of Mr. Richardson's. I think it is the most honest paper I have ever heard. It has shown us what can be done, and he has told us of a lot of his troubles. It is also evident that his sympathies are with the tool maker and the die maker, and I would advise everybody who has anything to do with the manufacture of these to obtain a copy of this paper. I think they will be prepared with all sorts of excuses to meet any trouble that arises. You will have noticed how different Mr. Richardson is from the usual type of lecturer who boasts of what can be done. I do not know how many salesmen happen to be here to-night, but they would not have admitted half of what he has told us. At the same time, Mr. Richardson, most of us, I think, are interested in production, and I do not think you will get very much sympathy for either die makers or tool makers unless you get good results. We want goods produced, and the only thing is, you will have to get over your troubles. When you do, the possibilities are untold. I handed an invitation to a friend and asked him to come to our meeting. He said he was previously engaged, but would have been very pleased to come. He said: "Just ask the lecturer how he would produce a moulding for, say, a front wing for an automobile, or a rear wing? Can he give us something that will take us away from those wretched steel things?" I would like Mr. Richardson to give us some idea of what the mould would be like for a job like that. A man who used to be a very great friend of the B.T.H. Company used to say, two or three years ago: "It is not long before we shall be making all the panels of the motor car." Can Mr. Richardson give us any inkling as to whether there is any possibility of these panel makers being put out of the way? A few years ago a man returned from the Malay States after spending about twenty years there on laying out rubber plantations, and he told me it was an absolute crime the way people were refusing to use rubber. He said the possibilities of using rubber mouldings, etc. were enormous, and he considered that in a few years time it should be possible that nearly all our furniture could be made of rubber compounds. I would like to know if Mr. Richardson can tell us if there is any question of rubber being restricted? The time element was rather disturbing. When I think of moulds I think of a machine I saw when I was an apprentice, making little tablets, and I remember this used to rip the

things off in the hundred thousands. You hesitate when you hear that a mould has got to be heated and wait a few minutes before it is handled. To get anything like big production you have got to have multiple moulds, and the trouble is, when you get these multiple moulds, there are variations. I could not help but smile when I saw the slide on the screen showing "What not to ask for." Well, Mr. Richardson, we cannot help it. Certain things are wanted and we shall have to ask for them. It is very nice when your suppliers simply tell you you must alter your design just to fit their ways. I did not quite understand when he spoke of standard heights. Just one word about hobbing. I know one or two gentlemen in Birmingham who have done some work of this nature in preparing stamping dies. They actually make a master and they practically make their stamping die by pressing this master into it, and I have seen several hundred of these. In producing these, arrangements have to be made to stop the plug from spreading sideways, but the job has been done very successfully and an enormous amount of die sinking done away with.

MR. RICHARDSON: It is rather a difficult task to design a mould for a wing in a few moments, but in the first place I would say that whilst it should be possible, we would have to have very high powered presses. I should visualise that mould as being of the flash type, because the design of the wing is really the type which I have called to-night the natural compression type, where the moulding gives its own compression volume in the mould. In the first place a mould of that description would be, of course, a tremendous weight and would have to be operated automatically. There would need to be some type of press to which would be fixed the top plunger, which would be shaped to the inside form of the wing. The mould itself would be mounted on the bottom press head, and I should imagine it would be steam heated either by coring out the underneath or by drilling the steam channels as already explained. We would have ejection and side cylinders on the press, which might be arranged to lift the top plunger out, and in this particular job I should say the work would release without any extra provision being made for discharge. The question of time. Take, for example, a large moulding, as shown here, made on a 700-ton press, the moulding operation took about six minutes and little or no special discharge arrangements were made, but the peculiarity of that moulding was this: as it shrank, the sides tended to concave, and two air blasts were projected down the sides of the mould which simply brought the moulding out as one would imagine a fountain with a ball on it.

Mr. Hannay said my sympathies lay with the tool makers. Well, naturally they do. One must consider the cost of the mould. At the same time, I think my sympathies are evenly divided, if not slightly more so, on the producer's side. If any of you have

been through a moulding plant and seen the moulders on a hot summer day, handling very big moulds, you would hardly wonder why my sympathies are with them. That is the point I tried to get home, the mould designer must cater for the moulder and provide suitable means for handling the mould. Mr. Hannay has pointed out that we mould designers must not ask for too many things, but we only ask these things for the producer's own sake, that is to give a cheaper article.

With regard to rubber mouldings. Personally I should not imagine that the future of mouldings is going to lie in the direction of the rubber field, because rubber when moulded has to be cured, and in the case of certain articles, this takes a considerable time. It is the practice in many companies to utilise a chain of moulds for the pressing operation and afterwards the chain of moulds is passed through a vulcanising oven for so many hours and then brought out with the mouldings cured. That means, if large production is wanted many moulds must be used. Ourselves, we get over that trouble by moulding probably from ten to fifteen minutes, and partially vulcanising the rubber, afterwards completing the vulcanising in a hot air oven as already described. That means that whilst the mouldings are being vulcanised, the mould is in production making other mouldings. Then again, if furniture and similar articles were made of rubber, we would require large plants to vulcanise them, and as the articles would not have a finished appearance, then definitely I should say that rubber is out of the question, because it does not take such a finish from the mould, and would have to be polished and in certain instances, machined, to get dimensional accuracy, if necessary.

With regard to the chart of points I wish to bring home. That was really put forward to point out that we do get designs asked for which I am sure could be simplified in many respects, and it was not intended to imply that we could not produce these—we can, but it means we make them at a loss to production time and also at larger cost of tools, and I do not think that there is any intention to limit the field of design. I think that if the designer of the piece and the mould designer got together, then the best results would come about.

The question of hobbing. I think there is only one word for it—it is wonderful to see the results that can be obtained by impressing a hardened steel hob into a blank of soft steel. I have never seen the dies referred to by Mr. Hannay, but I have no doubt the process is very much the same as employed with mould manufacture. There is also another interesting type of mould which I did not include in the paper because time was lacking: that is what is called " white metal " moulds, which are used mainly for rubber mouldings.

Mr. W. G. Groocock: The extraordinary part of the lecture

to-night which has been extremely interesting, was, to me as an old tool designer, that all the old truths we have learned in tool design are wanted in mould design. There are so many things to remember, I am not sure that we have got big enough heads to remember them all, and it is a very good thing for Mr. Richardson to come here and tell us all these things, because if you know the things you should not do, you have gone a long way towards doing the things which you ought to do. There is much design to-day that is not right for production, and I am quite satisfied that we have got to look to the design side if we are going to have the production that all of us desire. You mentioned materials, but did not say anything about one which I have heard quite a lot about, that is "Glyptal." I would like you to tell us whether "Glyptal" is moulded in the same way as synthetic resin compounds. I would like him also just to answer one question upon Mr. Hannay's mudguard, not that I intend to make a mudguard in that material, but would he use synthetic resin fabric for the material? He has mentioned hobbing and I think he has described hobbing very well. I saw it carried on in America and they were doing some really wonderful work. I would like him to tell us whether he has had any experience with chromium plating hobs to prevent wear and also chromium plating the moulds themselves to prevent wear. He mentioned the moulding of screws in position, but did not give us any light as to whether there is any compound put on the threads of the screw itself to make it easier to withdraw. Many of us may never enter the moulding field, but it is common knowledge. To those who may, and we never know how soon we may have to get into this business, he has given many interesting and instructive details of how things should be started, anyway.

MR. RICHARDSON: Mr. Groocock, with regard to "Glyptal," I am afraid that I cannot tell you anything about that. For one thing I am not a chemist, and I believe the chemists themselves are at present experimenting with this material, which is a water-white resin being moulded under similar conditions to the synthetic resin compounds. With regard to the moulding of the wing. I was about to mention that I think synthetic resin bonded compounds—that is, the bakelite or fabrolite—would be rather weak, and if we go on to fabric, which is much stronger, I am afraid the cost would be prohibitive. Apart from that, the moulding of fabric is more complicated than the moulding of powder because each layer has to be placed into the mould very carefully. Until we get down to something competitive with the present day wing, I am afraid the moulded wing must be something to come along in the future.

Chromium plating. We have had some experience of chromium plating, although we have not chromium plated hobs. I call to mind a few years ago when chromium plating was just coming along,

we decided to try it on a mould, and we found that the chromium plating in service tended to give way and to get into the moulding. Apart from this we do not utilise the chromium plating method at the present day because we use an alloy steel which is fairly cheap and is practically stainless. It has a very high tensile strength combined with great ductility, and I believe the main idea of chromium plating is to use mild steel of low tensile strength and to chromium plate afterwards to save expense. We use alloy steel which gives perfectly satisfactory results. With regard to the question of plating the hob. I do not think there is any point in plating the hob to give greater wearing qualities, because in the majority of cases hobs are made for one particular job and the master only produces perhaps twenty or twenty-five impressions, then is put on one side.

Moulding screws. Moulding screws are simply put into the mould, and powder is put around it. The powder under the action of heat and pressure fuses and begins to flow, flowing into every crevice of the mould and around the screw, and after a certain time hardens, after which it is infusible and cannot be affected by further heat.

Mr. Groocock raises the question of lubricating moulds. We do not lubricate the moulds for synthetic resin compounds. I believe the manufacturers of the compounds include stearic acid as part of the composition of the mould powder, which tends to act as a lubricant on the mould surfaces. We do lubricate rubber moulds by brushing them with flake soap that has been made into a wash.

Mr. E. G. Gregory : I would like to know what was really meant by the compression ratio ? Does it mean the area prior to going into the mould against the area of the piece after being pressed ? As far as hobbing is concerned, I wonder how the name " Hobbing " came about. Engineers do not associate it with this operation. A point that was stressed very much is that the bottom half of the mould should be highly finished for the hobbing process. One could understand that the top half should be highly finished, but why the bottom half ?

Mr. Richardson : Compression ratio. It is a question of the volume of the finished article to the volume of loose powder employed before it is compressed. In the case of the synthetic resin compounds the compression ratio we work to is about three to one, that is, the compound takes up three times the space in its loose form as the moulded article. That was the point stressed on natural compression mouldings, whereby that bulk of powder could be put in without building up the mould to obtain the required space in the mould. Fabric moulding : In the particular case you mentioned, the moulded spool, it is really approximately two to one compression, that is if we took about four of these sheets and compressed them under the required pressure we would find that

the finished sheet would be about half the thickness of the original material loaded into the mould. On the question of hobbing, I think that you have probably misunderstood what I said regarding polishing bottom faces. It is the top that is polished, not the bottom face. For this reason : if we left a rough surface we should find that even with the great pressures used the surface would still be rough in the cavity of the hobbed member. You can quite understand that it is much easier to polish and smooth off a hob and the blank surface rather than to try and polish an intricate depression after it has been hobbed.

MR. F. C. DOLBY : I should like to ask the lecturer if any of these materials set cold ? Was I right in understanding that some of these rubber mouldings take forty hours to vulcanise ? I have had some little experience in the rubber trade and never found any job need more than about two-and-a-half hours. Mr. Hannay's suggestion of making wings interested me very much. About fifteen years ago I had the job of making felloes for steam waggons out of a resilient, coir and rubber mixture vulcanised which stood bigger loads on the lorries than any timber ones, and were cheaper.

I might mention that I did suggest to one gentleman that instead of wooden stays for the body, they might be moulded in the same way, but my suggestion, I am sorry to say, did not come to anything, though I think it is quite sound.

MR. RICHARDSON : I did mention some mouldings made by the cold method. For instance, asbestos is cold moulded. The question of vulcanising. I should probably make myself clear by saying that we go up to these high figures especially for the electrical mouldings, because it is important that we cure them to the utmost so that no further shrinkage will take place when they are in service. In the case of smaller pieces, I explained that they would only take three or four hours. I certainly think there are a lot of pieces at present being made in wood and other materials which could easily be made from moulded compounds, but unless quantities are large and the pieces are not too intricate, probably we should find that in some cases wood pieces would be cheaper than the moulded articles.

MR. J. A. BOYES : I should like to ask the lecturer just what heat the moulds must be kept to and what is the effect of this on the workmen ? The working of the moulds will have a tendency to keep raising the temperature. What is the cooling method used to keep it within working range ? Scoring of dies : One speaker has remarked on chromium plating to prevent scoring and perhaps Mr. Richardson can tell us how a number of impressions can be taken without scoring of dies in flash moulds ? Is there a kind of coating or hardness given to the moulding on the outer face to a greater extent than the inner portion ? If this hard surface of the mould has to be worked mechanically afterwards, is there any great

risk of disturbing the form of the moulding ?

MR. RICHARDSON : The heat of synthetic resin compounds varies according to the compound being used. Some compounds are moulded at about 145° C. Fabrolite is moulded at approximately 170° C. The effect of the heat on the operator is very great, especially in the summer, and the whole point is that the mould designer must try to alleviate the physical effort made by the operator. So far as health is concerned, I do not think any of the operators have suffered to any great extent by this work. With regard to the scoring of dies. If we have a dish shaped moulding we never get any scoring because the moulding lifts itself naturally from the mould, but if we have a parallel type of moulding, which has to pass right through the mould, and especially if the mould is not hardened, we would find that after, say, twenty mouldings had been made, scoring would probably occur. This, of course, can be overcome by splitting the mould liner. Question of machining : There is very little to do on the synthetic resin compounds. Usually, machining is only necessary to remove flash and that is generally a buffing operation.

MR. I. H. WRIGHT : I am particularly glad to propose a vote of thanks. Mr. Richardson's paper is, in my opinion, a perfect model, so far as our experience goes yet, of the kind of paper that the Institution of Production Engineers should have presented to it. It is also particularly appropriate that so new and rapidly developing a subject as this should be brought before so new and rapidly developing institution as the Institution of Production Engineers. Referring to the possibilities of some of the things that have been mentioned, synthetic furniture made of synthetic resin compounds has been talked about. Furniture has been made for quite a long time of Ferro Concrete which is quite light. That is one form, and with the provision of efficient moulds and methods of manipulation, no doubt many of the synthetic materials and mixtures of all kinds by which one understands one which has a chemical reaction on being mixed and pressed, are something of the future which we shall have to think about more than we do. I don't know how it will be when you want to drive nails into it—you will probably have to have the holes cast in, and according to Mr. Richardson you will not have to have the holes too deep. I have great pleasure in proposing a vote of thanks to Mr. Richardson for the exceedingly practical and instructive paper he has given us to-night.

MR. E. W. FIELD seconded the vote of thanks, which was cordially adopted.

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(6th February, 1930).

MR. H. E. WEATHERLEY said one point that occurred to him as important was the standardisation of moulds so that according to the size of the article to be moulded the correct height could be obtained by placing two or three pieces in the press together. Might not this also be carried a stage farther by splitting the dies because this would reduce the cost of producing the die. It seemed that many articles would be made of the materials discussed in the paper and produced in sections and cut by standard tools, all of which would considerably cheapen production.

THE AUTHOR replied that it is necessary rigidly to adhere to standard heights for the moulds, otherwise there would be confusion in the moulding shop. That was the practice of the B.T.H. Co., and most manufacturers had their own methods for achieving the same object. It was very necessary to standardise the moulds in some form. With regard to split dies, the best policy was to avoid them wherever possible, although there were cases where it would be impossible to produce both the moulds and mouldings without splitting the dies. Nevertheless, he found solid moulds preferable. He could hardly imagine a general standardisation of dies and cutters, however, although in the case of his own firm they kept standard radius cutters in stock and the mould designer was given a list of these and could call for them wherever possible.

MR. SALMON said his experience was that polished moulds are essential to increased production; moreover, the life of such moulds was longer. What were the author's views with regard to chromium plated moulds; he believed it had been used successfully but, on the other hand, there seemed to be points against it. Although the author had suggested that the polished moulds required no attention, he disagreed with that view because the polished mould required all the attention that could be given to it. Again, the suggestion in the paper that moulds got better and better with use must have some limitation, otherwise it would appear that the moulds never wear out.

THE AUTHOR speaking with regard to polished moulds said the higher the polish the better the finish on the article, because the polishing polished out tool marks which might show on the finished article. He found that the type of steel used in the B.T.H. works tended to keep a very bright polish and although he agreed that the improvement only went on to a certain degree, the impression given was that the polish on the moulds got better with continued use. This, however, only referred to automatic and semi-automatic moulds, because with hand moulds these were often badly knocked about in the shop and became scored. He had tried chromium

plating when first this came out some years ago. He was then using mild steel moulds and it was found that after chromium plated moulds had been in service for a short time, the plating flaked off and thereby caused trouble because some of the flaking got into the material used and caused shorting electrically when the finished articles were put into service. Therefore his firm did not chromium plate moulds now as it was considered that the steel now used gave all that was desired. The steel used was not very much more costly than mild steel and it had a very great tensile strength combined with high ductility. It took a high polish and having secured this they never pursued chromium plating any farther. He quite agreed that careful attention should be given to moulds because of the relatively high cost.

MR. TRIMBEE asked what limits in production were considered commercial in this work and was the multi-system adopted as in foundries, using moulds for producing a number of the same articles at the same time, i.e. one mould producing, say, half-a-dozen at once.

THE AUTHOR said the question of limits was a vexed one and at the Coventry discussion someone had suggested that he could obtain any limits he required. This was not within the author's experience. Generally speaking limits of approximately plus and minus .005″ could, as a rule, be obtained, this even depending on circumstances. Multi-impression moulds were, of course, designed and used in mould practice, although the methods for using these were naturally different from those used in foundry practice.

MR. CLARKE asked if any automatic methods of delivery of the powder to the moulds had been tried. Also was there a standard stainless steel for dies. Further, what was the method of release for a threaded part. Was it the same as with a die casting ?

THE AUTHOR said he was not aware of the adoption of automatic delivery in any works in this country although he believed that in America, where certain parts were being manufactured in large quantities, automatic delivery of the powder or pellets had been adopted. A stainless steel was only necessary for dies when using urea products for the moulding material, but it was not absolutely necessary to use it for ordinary synthetic resin moulding powder. As to the release of screwed parts from dies, they must be unscrewed out of the mould, although it was possible to make a split threaded die to facilitate discharge.

MR. SALMON remarked that the author had spoken of the absence of distortion when removing the part from the mould and later on in the paper it was suggested that they should be put in a cooling place and wetted. He himself had found trouble from distortion and it seemed that distortion took place immediately the piece left the mould. To get that under control was a very difficult matter.

THE AUTHOR replied that he had said there was no fear of trouble-

some distortion. Mouldings varied, but the experienced mould designer and moulder usually had an idea, when the mould was made, what was likely to happen so far as distortion was concerned and they took steps accordingly. Many specifications said that such and such a face must be perfectly flat and then it was up to the mould designer to try and visualise where the distortion was likely to occur and provide some means of keeping the faces flat whilst they were cooling.

MR. R. W. BEDFORD said he gathered it is not possible to control colour in the case, for instance, of domestic articles. Had there been any recent developments in that connection?

THE AUTHOR said it is impossible to control mixed colours in the sense of retaining a pattern, because owing to the high pressure employed the powder or raw material was forced in all directions. The only way to carry out a colour scheme would be to mould in moulded inserts, which, of course, would be very expensive.

THE CHAIRMAN, MR. A. BUTLER, asked how the electrically-heated platten shown on one of the illustrations of presses, worked? Was it cheaper than steam, or was it more convenient in certain cases? There seemed to be great possibilities in that direction. A matter the author did not say much about was the limits for inserts. In the case of a number of mouldings he had had to do with for electrical work, something quite extraordinary was asked for in the limits for inserts. A year or two ago it was very difficult to locate inserts properly, so that they did not move and it would be interesting to know if there had been any improvement since in the matter of holding inserts in the moulds so that nothing more than ordinary commercial limits need be called for. As to the hobbing process he was surprised the author mentioned such a low pressure as 200 or 300 tons. He himself had tried getting impressions with about 100 tons, but had never had any luck at all. Whether doubling the pressure made all that difference, he did not know. Perhaps the author could give some idea of the hardness of the hob he used either in Brinell or Scleroscope numbers. With regard to side pressure, where it is arranged by means of taper sleeves, the author called for a minimum of eight degrees taper on the sleeve, but it would be interesting to know whether that was varied in certain cases in order to obtain the right compression ratio.

THE AUTHOR said that where the moulding material was actually to cover the insert, no limits were required. Limits were only asked for where the insert was to form part of the actual mould, because when the mould was made a certain size it was possible, without limits on the insert, for the insert to be too large or too small. As much as 200 tons per square inch pressure was sometimes used on the hobs, the pressure required, however, depending on the total area of the piece to be hobbed. The use of electrically

heated plattens mentioned was for a special job for which special presses were used. The experience had been that now and again an electrical heating unit would burn out with the result that the temperature of the mould would fall appreciably. He had no relative figures on cost of electricity and steam for heating. It was claimed that electricity was slightly cheaper than steam, but against that there was the trouble from heating units burning out and holding up production so that on the whole he thought steam was best. No doubt the design of electrically controlled plattens could be improved to overcome the difficulties mentioned. The side pressures on taper moulds were only needed with fabric moulding composition, which had its particular moulding peculiarities, and so far it had not been found necessary to vary the tapers.

MR. WILSON referred to a description of a German mould which was made in two halves. He imagined there was an opening at the top into which the moulding powder was poured and where it was under control by the operator. Had the author any experience of this machine?

THE AUTHOR said he had heard of that idea. So far as he could say the powder was in a separate container which was over the top plate of the mould, this powder being pre-heated and obtaining a certain amount of plasticity. At a pre-arranged time a plunger came down and squirted this plastic material into the mould. He believed the Americans had tried working moulds on this principle, but he did not know whether it had been attempted in this country.

A SPEAKER asked what is the toughest steel for hobbing and whether it is possible to use nickel-chrome steel or stainless steels?

THE AUTHOR replied that the best material for hobbing was practically pure iron. Any alloy steel could not be successfully hobbed. The steels his firm used for hobbing purposes had a tensile strength of approximately thirty tons. Above that figure difficulties were met with.

Replying to the chairman's request for information of the hardness of the steel used for hobbing, the author said the Brinell figure was about six hundred. It was a definitely hard steel containing 12 per cent. chromium and 3 per cent. carbon, and it was ideal for hobs.

MR. LANG asked how the temperature of the heat was controlled when using steam, especially when there were several branches tapped off the main supply. He had used steam for a long time and found it very difficult to control. He had also found steam plattens gave trouble from cracking and had tried gas for heating local spots. Could the author say how the cutters stand up in gear blank work cutting a wheel, say, with a 28 D.P.? Again, was any lubricant better for hobbing than others?

THE AUTHOR speaking with regard to steam temperature control, said a pressure at the boiler of approximately 140 to 150 lbs. should

maintain a temperature round about 350° F. The temperature of hand moulds was more or less kept constant by the fact that they were being taken out of the press and put back again, and this prevented overheating. He had seen gas used, but was not struck with it ; it seemed a very crude method. Vaseline was the lubricant used for hobbing and as to the machining of gear blanks it was generally agreed that whilst H.S.S. cutters gave a certain amount of satisfaction, they did not last long without re-grinding, as this material was of an abrasive nature.

On the motion of Mr. H. R. Bedford, seconded by Mr. H. E. Weatherley, a hearty vote of thanks was accorded the author at the conclusion of the discussion.